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FUNCTIONAL DISORDERS OF APPLES

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PART I

FUNCTIONAL DISORDERS OF APPLES ON THE TREE

A number of functional disorders such as drought-spot, internal cork, corky-core, tree-pit and water-core, which affect apples while still on the tree, are of definite economic importance in Canadian apple orchards. There is a wide variation in the prevalence and severity of such disorders from season to season, influenced as they are by seasonal climatic conditions. Wide fluctuations of soil moisture and particularly a period of drought cause some of them to be more prevalent.

The study of these disorders has been complicated, on the one hand by the fact that different names have been given by workers in various parts of the world to what appear to be one and the same disorder, and on the other hand by the fact that the same name has been applied to different disorders. Descriptions will therefore be given of the main types of disorder and any evidence that a particular one can or cannot be cured by boron or any other treatment will be mentioned.

Classification and Description

The first four disorders mentioned above may be divided into two groups. The first group expresses itself in the form of drought-spot, internal cork and corky-core, the direct cause of all three being a deficiency of boron and the control of which is the application of boron in an available form. Tree-pit may be expressed in two symptomatic forms; typical bitter-pit and blotchy-pit. The pit types of disorder are apparently due to some different condition than that responsible for the first group, since they cannot be cured by boron, nor is any definite control yet known.

Drought-spot or Superficial Cork

This type of cork may appear very early in the life of the fruit. It first appears as irregular small to large light brown russeted patches on the skin. (Plate I, Fig. 1.) These areas later become rugose, darker brown in colour, and as they grow become roughened and cracked. The lesions may not extend into the flesh, but if they do, only a few layers of cells are generally affected, although in severe cases deep cracks or splits may be formed. (Plate I, Figs. 2, 5 and 6.) The disorder has been noted on specimens of the following varieties either alone or associated with internal cork or corky-core: Fameuse, McIntosh, Wealthy, Stark, Northern Spy, Salome. Superficial cork exhibits somewhat different symptoms on the variety Ben Davis. (Plate I, Figs. 3 and 4.) The initial russeted areas are not present but the fruit is malformed due to irregular depressions, dark brown in colour. Internally the lesions are found involving the skin or within 2 mm. of the skin. They are dark brown in colour and usually show a green border.

Internal Cork

This disorder often appears when the apple is but half grown. Fruits affected at this early stage in their growth increase but little in size and often drop badly. Affected fruits may be detected on the tree by the blushed or red portion of the apple being somewhat darker in colour than is normal. In some varieties fruit affected early in its growth becomes markedly deformed or knobby, a condition brought about by a large number of discontinuous elevations

or depressions. (Plate II, Fig. 3.) In other varieties, affected later in their growth, there is no external evidence of the disorder. Upon cutting open affected fruit, light brown spots of dead, cork-like material will be found in the region of the core or scattered indiscriminately through the flesh. (Plate III, Fig. 1.) The Fameuse variety is particularly susceptible to this form of cork.

Corky-Core

In this type of disorder the affected tissue is generally confined to the core area as one or more light brown patches, or as a continuous band of brown tissue. (Plate III, Fig. 3.) No lesions occur in the cortex and there is no malformation of the fruit. This type of cork disorder may appear when the fruit is half grown. As there is no external symptom it is only by cutting into the apple that the trouble may be detected. The McIntosh variety is particularly susceptible to this type.

Tree-Pit, Typical Type

Pitting does not show up until the fruit is approaching maturity or may not show up until the apples have remained in storage for some time. The first cells to be affected are the pulp cells and from these the disorder works outwards; so that in the initial stages dark spots may be seen through the skin before an actual depression or pit is formed. The areas over these spots become depressed or sunken and are comparatively small and regular in outline. (Plate II, Fig. 1.) The colour of the surface spots is usually brownish but varies from grey-green to reddish-brown. A somewhat different appearance is shown in Plate II, Fig. 5, in which the normal-coloured pits are encircled by a reddish-brown halo of lighter colour. The brown spots extending into the flesh are mostly small and generally confined to a few layers of cells just underneath the skin. (Plate III, Fig. 2.) Cut fruits may show numerous similar lesions distributed between the skin and the core area. The pits are usually more numerous towards the calyx end. Pit disorders are more prevalent on late-maturing varieties such as Northern Spy and Baldwin.

Blotchy-Pit

In this case the pits are less clearly defined, irregular in outline, larger in size, less sunken, deep green or mottled green and brown blotchy depressions. Large brown necrotic areas are found in the flesh near the core or close to the surface. (Plate II, Fig. 6) Such lesions may be brown and spongy with an indefinite outline similar in appearance to a bitter-pit lesion or the lesion may have a definite faded greenish border similar to that of internal cork. However, this type of lesion cannot be confused with internal cork owing to the difference in external appearance.

Effect of Soil Type on the Incidence of the Cork Group of Disorders

Investigations in eastern Ontario and Quebec have shown that cork disorders are more prevalent and much more severe in orchards located on poor soil types; shallow soils underlain by compacted subsoils, poorly drained soils and soils high in lime in the form of calcium carbonate. Even in fairly deep soils these disorders may be prevalent if the soil reaction is alkaline and calcium carbonate is abundant. On the other hand, high-lime conditions are not associated with these disorders in British Columbia where they may be due to an

actual deficiency in the soil, whereas in other parts of the country such as Ontario and Quebec they may be due to a tying up of boron by high-lime conditions. In New Zealand the greatest amount of cork has been found on shallow soils, highly deficient in lime. In general, it may be said, however that a high-lime content resulting in high alkalinity restricts the availability of boron in the soil (3).

Effect of Cultural and Fertilizer Practice upon the Incidence of Cork Disorders

A survey conducted in some 160 Ontario orchards, indicated that those under a system of sod culture suffered less than cultivated ones. Trees of excessive vigour, exhibiting high-nitrogen symptoms appear to be more prone to these disorders. Many cases were found where these disorders were associated with manurial practice, especially the use of excess quantities of pig or hen manure (4). Askew *et al* (1) made determinations of the boron content of leaves and fruits under conditions of boron deficiency and boron applications. The results suggest that the apple tree meets in the first instance the requirement of the leaves for this element, and, in the case of deficiency the fruits fall in boron content long before an appreciable decline can be noted in the leaves. Therefore, a factor which tended to favour extensive leaf development would create an intensified boron deficiency in the fruit.

Trees of the Melba variety were grown at Ottawa in pots under varying nitrogen conditions but with the moisture maintained at an optimum. Internal cork varied from 0 to 100 per cent and was correlated with nitrogen applications. Under low-nitrogen conditions or where nitrogen was withheld after early spring the disorder was absent. When nitrogen was fed only until the trees were in full bloom each season the amount of cork was 6 per cent, when fed until the calyx had closed, internal cork rose to 15 per cent and when fed until September 1, all of the fruit was affected.

Direct Cause and Control of Cork Disorders

Atkinson (2) first reported that the injection of 4, 5 and 8 grams of boric acid per tree reduced the amount of affected fruit to 0, 3 and 0 per cent, while untreated contiguous trees showed 36 to 100 per cent affected fruit. McLarty (6) independently found that drought-spot and corky-core of apples could be controlled by the use of boron. Young and Bailey (9) reported control of corky-core by injecting boric acid or borax into the trunks of apple trees. Hill and Davis (4) also reported control of internal cork, corky-core and drought-spot by injections of boric acid. Askew (1) found that fruit from healthy trees contained 10 to 13 p.p.m. of boron while fruit from trees affected with internal cork contained 3 to 8 p.p.m, the amount being inversely proportional to the severity of the ailment. He found that one-half to one pound of borax distributed around each tree or 50 to 100 lb. per acre is a safe procedure to employ in preventing cork in apples. He also found that spraying with borax solutions is also a practicable method of control. Two sprays with 0·25 per cent borax, separated by an interval of 20 days are recommended as the safest procedure. McLarty and Wilcox (7) recommended broadcasting boric acid crystals around the trees at the rate of 8 oz. per tree over the area of a circle at least 20 ft. in diameter.

As a result of a series of experiments conducted by the Horticultural Division, Central Experimental Farm, Ottawa, the following recommendations are made.

Orchards on acid soils

A few ounces to one pound of borax or boric acid per tree, according to age, or not more than 30 to 50 lb. per acre, worked into the soil if possible. Applications may be made in the fall or spring. If a spring treatment is adopted the application should be made very early in order to have an effect the same season. To apply this small quantity, the borax may be mixed with several times its volume of sand or dry soil as an aid in spreading. A single soil application in the fall of 1936 was found effective during 1937 and 1938.

The foregoing recommendations should not be considered as an annual treatment, since there exists the possibility of creating toxic concentrations of boron. A single treatment has been found effective for at least two seasons. The safest procedure would be to forego a second treatment until the disorder again makes its appearance.

Orchards on alkaline soils

If the soil is alkaline and high in calcium carbonate, effective control may not be obtained by soil applications in a season when very low soil moisture conditions exist. More effective control may be obtained under these conditions by incorporating borax with the spray. The disorder may be controlled by including borax in the calyx and second cover spray at the rate of $2\frac{1}{2}$ lb. to 100 gallons of spray.

Conditions Associated with the Occurrence of Tree-pit

The experimental results to date indicate that boron treatments have no effect on the control of tree-pit of apples. Severe pruning frequently brings about an incidence of bitter-pit. It has been noted that the disorder is generally more prevalent in seasons of light crop when fruit is of excessive size. Very often continuous applications of manure or highly nitrogenous fertilizers increase the severity. Tree-pit does not appear to be intensified by alkaline soils high in calcium. McAlpine (5) attributed the trouble to a physiological disturbance and upheld the theory that a moisture deficiency in the cells of the fruit during a critical period of growth was the cause. No definite control is yet known, but pruning, cultural and fertilizer treatments which promote excessive growth should be avoided with susceptible varieties.

Water-core

This trouble also commonly known as glassiness, may be recognized in the early stages or when the disorder is not severe only by cutting open the fruit; no external symptoms are evident. Glassy areas may then be observed close to the core, around the vascular bundles or in radiating lines; they appear to be water- or sap-injected. Later, large areas of flesh may become involved and the disorder progresses outwards to the skin, portions affected attaining the characteristic glassy appearance. If the fruits are severely affected when picked, a general breakdown of the tissues occurs in storage, but if slightly affected the water-core areas may disappear.

No satisfactory control measures have yet been found but it is considered to be more prevalent on young trees just coming into bearing, especially where high nitrogen conditions prevail. The growth of young trees of susceptible varieties should not be forced by heavy applications of nitrogenous manures. At Ottawa it has been found that injections of a nitrogenous salt directly into the branches of a susceptible variety more than doubled the amount and severity of the disorder compared with water-injected or untreated branches.

It has been observed by other investigators that the trouble is more prevalent in wet years, and still other authorities consider that high flesh temperatures of the fruit is a major factor.

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PART II

FUNCTIONAL DISORDERS AND FUNGAL ROTTING OF APPLES IN STORAGE

The subject of functional disorders in stored apples has received vigorous attention in Canada during the past five years, due to the increased demand for better quality fruit, both on the home and overseas markets. There has followed a desire for improved storage facilities and many storage troubles hitherto of no commercial importance have now assumed proportions which necessitate investigation and control.

It may be said that the use of synthetic fertilizers in orchards has possibly been partially responsible for an apparent increase in functional disorders in fruits on the tree and in storage. The role of minor element deficiency is seen in the more recent severe outbreaks of cork in apples and, although this disorder originates in the orchard, it is frequently only noticed after the fruit has been placed in storage.

The gas storage method is now occupying the attention of Canadian workers and gives much promise as a means of avoiding the various types of low-temperature breakdown with certain varieties of apples. Nevertheless, a full understanding of the limits of gaseous toxicity must be obtained, in order to eliminate functional disorders in artificial atmospheres.

Certain obscure types of internal breakdown which have been found are described, not with a view to rendering the subject more complex, but with the hope that they, along with the more common forms, may be classified not on the basis of appearance but on the basis of causation when such knowledge is complete.

It is felt that the term 'internal breakdown' is too broad in concept, in the light of varietal reaction to storage conditions. This classifrcation is thus based, for the most part, on that adopted by Plagge, Maney and Pickett (20).

Classification of Functional Disorders and Fungal Rots

Low-temperature breakdown	Soft scald Soggy breakdown (including 'frog eye' type) Internal browning
Breakdown associated with senility	Jonathan breakdown Mealy breakdown Core flush (Core browning) Cortical flush Vascular breakdown
Breakdown associated with the storage atmosphere	Gas storage injuries Scald (superficial) Scald breakdown
Breakdown associated with orchard conditions	Bitter-pit (storage pit) Water-core (Water-core breakdown) Cork (Corky breakdown)
Fungal Rots in storage	Blue mould (Penicillium spp.) Alternaria rot (Alternaria spp.) Grey mould (Botrytis spp.) Black mould (Rhizopus spp. and Mucor spp.)
Not classified	Jonathan spot Lenticel spotting Freezing injury

Low Temperature Breakdown

Soft Scald

Soft scald has not been encountered to any great extent in Canada, although the disorder has been observed on Wealthy and Jonathan apples.

The term soft scald is very misleading as the disease is a form of low-temperature breakdown and is in no way related to the scald which is of major importance, namely, superficial or apple scald. This disorder is characterized by sharply defined patches, often ribbon-like, of brown tissue on the surface of the apple. The browning may extend to a depth of one-eighth of an inch or more beneath the affected area and in more advanced stages the disorder resembles soggy breakdown and may eventually involve the entire apple. Soft scald is associated with low temperature storage (32° F.) and delayed storage appears to render the apple more susceptible to this disorder. (Plate IV, Figs. 1-2.)

Recent investigations in the United States indicate that storage in 20 to 30 per cent carbon dioxide for 2 days before storing at low temperatures is effective in controlling soft scald. (9, 16, 18, 19, 20.)

Soggy Breakdown (including Frog-eye type) (See Plate IV, Fig. 3, and Plate V, Fig. 1)

This disorder is considered to be essentially a low-temperature type and has been observed on Grimes Golden in British Columbia, Cox Orange and Ribston in Nova Scotia, and to a slight degree on Fameuse apples at Ottawa, all being obserbed at 32° F.

Soggy breakdown makes its initial appearance near the skin as a light brown discoloration of the flesh, lacking definition. As the disorder progresses, the colour darkens and the breakdown moves inward toward the core area and also toward the skin, but at a slower rate. In the earlier stages of the disorder, the discoloured portions may occur as isolated areas of bands in the cortex, while in severe cases a complete ring of brown spongy tissue is present. The core area frequently remains unaffected. Badly affected fruits may be detected externally by a brown discoloration of skin which is spongy to the touch and when cut by well defined dark brown areas, with soggy tissue on the cut surface of the fruit (Plate IV, Fig. 3). Another distinguishing feature is that the fruit becomes dull in appearance as distinct from the normal external appearance of fruits affected with mealy breakdown.

It has been observed that both the Gravenstein and Wagener apples are susceptible to a type of low-temperature breakdown at 32° F., which resembles mealy breakdown. With other varieties, the latter disorder is associated with senescence and not specifically with low storage temperatures. However, neither the Gravenstein nor the Wagener is subject to breakdown at 38° F., and in view of its early appearance at 32° F., senility would hardly seem to be the causal factor.

In studies with fruits subjected to pure nitrogen at room temperature, it has been found that lesions similar to those described above develop. It is possible, therefore, that there is interference in the uptake of oxygen at low temperatures.

Another peculiar form of breakdown, similar to the soggy class, was observed in Blenheim apples at 32° F. This was designated as the "frog-eye" type (Plate V, Fig. 1). The affected apples showed clearly-defined brown areas on the skin in the centre of which was a circular area of healthy tissue. The tissue beneath the discoloured area was affected and extended well into the cortex completely encircling the core of healthy cells beneath the normal area of skin (14, 17, 18, 19, 20, 21).

Soggy breakdown is closely related to soft scald, and responds to similar storage treatment. Apples that are subject to it seldom develop the trouble at 36° F. or higher. Delayed storage is a factor in increasing this disorder, so that immediate storage is desirable for susceptible varieties.

Internal Browning (see Plate V, Fig. 2)

This disorder has been reported from British Columbia only, where it was found to affect the Yellow Newtown apple in storage at 32° F.

Internal browning is characterized by lines of firm, brown tissue that radiate from the core area which is usually light brown in colour (Plate V, Fig. 2). It is necessary to cut fruit in order to detect the trouble, as there are no external symptoms (20, 21, 23).

Breakdown Associated with Senility

Jonathan Breakdown (see Plate VI, Fig. 1, A and B)

This disorder occurs in several varieties of apples in British Columbia, but the Jonathan is particularly susceptible, and growers have suffered serious financial losses as a result.

The breakdown makes its appearance in storage several weeks after harvesting and is first seen as a light-brown discoloration of the flesh with no external symptoms. The discoloured areas are indefinite in outline and usually originate near the skin, or in the region of the vascular bundles. The core area and that immediately adjacent to the stem are seldom injured. As the disease progresses, the skin becomes dull in colour and the fruit as a whole softens in texture (Plate VI, Fig. 1, A and B).

The Jonathan apple has been shown to be highly susceptible to water-core, particularly in late-picked fruits, and this in turn has been associated with the breakdown occurring in this variety in storage. It has been suggested, therefore, that the water-core condition may be a precursor of Jonathan breakdown. However, it is difficult to reconcile the following two specific characteristics of these diseases with this association: (1) water-core tends to disappear when apples are placed in ordinary storage temperatures (40° F.-50° F.) and (2) the development of Jonathan breakdown is retarded by storage at low temperatures (32° F.).

Control measures for Jonathan breakdown as outlined at the Summerland Experimental Station are as follows:

(1) Susceptibility of Jonathan apples to breakdown is increased by an orchard environment which promotes vigorous growth.

(2) Breakdown can be prevented by picking the apples at the proper stage of maturity.

(3) Change in colour of the skin on the unblushed side of the fruit is a fairly reliable maturity index.

(4) Trees carrying a light crop should be picked earlier than those which are heavily laden.

(5) The development of breakdown can be delayed but not prevented by storage at low temperatures.

The Experimental Station at Summerland, B.C., has issued a colour chart for the use of growers, which includes three colours representing three stages of maturity. The intermediate stage, yellow-green, is the one recommended as the best condition for picking the fruit in order to obtain good keeping quality (6, 13, 16, 20).

Mealy Breakdown. (See Plate VI, Fig. 2)

Mealy breakdown is a functional disorder found in many varieties of apples including McIntosh, Fameuse, Wagener, Gravenstein, Cox Orange, King, Ribston, Macoun and Lobo. This type of breakdown is associated with senescence and is seen as dry, dark brown areas of tissues and may occur initially either immediately beneath the epidermis or in the core region. Examples of skin cracking have been observed in the McIntosh and Ribston varieties at 38° F.

On the basis of recent findings, early-picked fruits appeared to keep better than those picked later, when stored at 32° F. but at a temperature above 36° F. the reverse is indicated. In view of the results obtained with Wagener, Cox Orange, Ribston and Gravenstein in storage, it is recommended that temperatures below 36° F. should be avoided (18, 19, 20, 31).

Core Flush (see Plate VI, Fig. 3)

Throughout Canada, many varieties of apples, including McIntosh, Fameuse, King, Baldwin, Wagener, Cox Orange and Gravenstein, are subject to this functional disorder in storage.

As the term ' core flush ' implies, the disorder appears as a homogeneous flushing in and around the core, the cells turning a light brown colour with no clear definition between the healthy and diseased tissue. The browning deepens in colour as the affected apple ages, but there is no appreciable enlargement of the area.

Core flush has been associated with the senility of apples, but this view is difficult to accept in the light of varietal reaction.

Studies with McIntosh apples indicate that immature apples stored at 32° F. are more predisposed to core flush development than apples picked in a mature condition. On the other hand, the stage of maturity at which Fameuse apples are picked appears to have little influence on core flush under similar storage conditions. In this connection, a ground-colour chart for harvesting McIntosh and Fameuse has been published. Copies of this chart may be secured on application to the Division of Horticulture, Central Experimental Farm, Ottawa. Sometimes, there appears to be a decrease of core flush development when McIntosh apples are subjected to delayed storage for one or two weeks.

In respect to this disorder, a statistical study of lots of McIntosh and Fameuse apples revealed that temperatures of 36° F. to 40° F. seem best suited to the keeping of McIntosh whereas 32° F. is found to be best for Fameuse. Although storage temperatures of 39-40° F. reduce the amount of core flush of McIntosh, they are not suitable in ordinary cold storage owing to the greatly increased shrinkage of the fruit that results. Such temperatures may be employed without the occurrence of core flush or undue shrinkage if employed in conjunction with gas storage.

Other varieties found susceptible to core flush at temperatures around 32° F. are Gravenstein, Yellow Newtown, Cox Orange, King and Wagener, whereas the Baldwin variety develops more of the trouble at 40° F.

Storage studies with Yellow Newtown and Grimes Golden apples in British Columbia indicate the development of core browning at 32° F. which may be reduced by delayed storage. Core browning may be related to core flush as the delayed storage effect appears to be the same for each (7, 14, 22).

Cortical Flush

Cortical flush has been found in McIntosh apples in Nova Scotia only. This illustrates the importance of locality insofar as storage disorders are concerned.

The disorder makes its appearance as a very light, golden flushing in the cortex of the apple. The affected tissue deepens in colour as the storage life proceeds. It is confined to cellar storage conditions and is first seen after four months' storage in apples picked too immature. Such fruit becomes shrunken at about the same time as the discoloration makes its appearance.

Vascular Breakdown. (See Plate VII, Fig. 1)

This is a type of internal breakdown which is peculiar to Nova Scotia and affects Gravenstein, Wagener, Ribston and McIntosh apples.

As the term implies, the disorder is initiated in the ten main vascular bundles and is characterized by well defined, dark brown necrotic areas often irregular in outline. The flesh in these areas may collapse, and as the storage season advances, the spots may enlarge until the entire tissue of the fruit assumes a brownish, water-soaked appearance. Ordinarily, however, it is necessary to cut the fruit in order to detect the disorder. The disorder does not appear to be confined to any particular temperature condition as it has been found at 32° F., 35° F. and in cellar storage (40° F.—50° F.).

Breakdown Associated with the Storage Atmosphere

Gas Storage Injuries (including Brown-heart)

The injuries which are sustained by fruit in gas storage may be due to excess carbon dioxide or deficient oxygen in the atmosphere or to combinations of these gases under certain temperature conditions. The problem of classifying such functional disorders is rendered the more complex because of specific varietal reaction. Furthermore, the tolerance of fruit towards various gas mixtures varies with the senescent state of the fruit. For example, in the case of McIntosh it has been found that the earlier-picked apples are more susceptible than the later-picked fruit.

Brown-heart, which is generally associated with carbon dioxide injury, is an accepted term for a disorder which under certain conditions may possibly be due to an oxygen deficiency. At the present time, investigations are under way at Ottawa, which, it is hoped, will serve to elucidate the factors concerned with the development of brown-heart. With the above reservations, mention will be made of some forms of brown-heart observed in Canada. (Plate VII, Fig 2).

McIntosh apples stored in pure carbon dioxide for short periods exhibit a form of flesh collapse which occurs in small necrotic areas appearing as widely distributed spots throughout the flesh of the apple or as five distinct equidistant spots around the core line. (Plate VII, Fig. 3) Cox Orange apples, when stored in 10 per cent carbon dioxide for several months, develop the type of brown-heart most commonly described. This appears as small patches of dark brown tissue either within the core or in the region of the main vascular bundles. In severe cases, the entire fruit may become involved, assumes a dull or cooked appearance externally and is spongy to the touch.

McIntosh apples, when subjected to a treatment of 100 per cent nitrogen at 40° F. have been observed to develop a condition similar to a certain type of soggy breakdown wherein clearly defined bands of necrotic tissue develop in the cortex. In addition, it has been noted that when apples of this variety are removed from storage at 32° F. and given the above treatment at room temperature for five days, a removal of the red pigmentation takes place. (Plate VIII, Fig. 1).

With regard to temperature effects, experiments have shown that McIntosh apples are more severely injured at 32° F. than at 40° F. when treated with 20 per cent and 100 per cent carbon dioxide.

A type of superficial scald has been observed in Golden Russet apples which have been stored for seven months in atmospheres of 5 and 10 per cent carbon dioxide at 40° F. McIntosh apples which were removed from storage in 7·5 per cent carbon dioxide at 40° F. for two months did not show scald, but if stored for a longer period practically all the fruit, which was not oil wrapped, developed scald. This becomes more noticeable on removal to higher temperatures. (7, 9, 13, 14, 20).

Gas storage injury often takes on an external form. (Plate VIII, Fig. 2). This first shows as a brown, crinkly condition of the skin surface. These areas are more or less localized. In severe cases the affected areas may be considerably depressed. The flesh immediately under these areas may become dried and hard. The disorder rarely becomes more than superficial. External gas storage injury is the common type on McIntosh and is sometimes found on Fameuse and Northern Spy.

Scald (Superficial) and Scald Breakdown

This trouble is very widely distributed and the majority of the apple varieties are affected to some extent by this disorder. Among the varieties most seriously affected are Wagener, McIntosh, Rhode Island Greening, Baldwin, Jonathan and Yellow Newtown. (Plate VIII, Fig. 3, A & B).

Scald makes its appearance on the skin of the apple in the early stages of storage life or after removal as a superficial browning, irregular in area, usually on the unblushed side of the fruit. As the storage season advances, the areas affected may enlarge and the tissue immediately beneath may take on a brown discoloration to a depth of about half an inch, a condition which is designated as scald breakdown.

As has been indicated, the trouble is more prevalent on green fruits, and experiments with McIntosh apples indicate that immature fruits are more susceptible than those which are mature. In addition, it has been found that if immature fruits are subjected to delayed storage at higher temperatures for two weeks, the trouble is greatly reduced.

With McIntosh it has been found that scald will develop more at 32° F. than at 40° F. but no satisfactory differences have been found with the Wagener variety. Removal of fruit from 32° F. to 60° F. is another factor conducive to scald development.

The use of oiled wraps and oiled shredded paper has been found a satisfactory control measure for scald, although control has not always been obtained in oiled wrapped fruit which was removed from cold storage to a temperature of 62° F. (4, 7, 9, 13, 20, 21). There has also been observed on Gravenstein apples what is generally referred to as light-induced scald, which occurs when apples are removed from the package and exposed to light. This disorder shows up as a brown discoloration, diffuse or spotted, with the lenticels browned and more or less raised above the general level. It is usually confined to varieties with little or no red colour.

Breakdown Associated with Orchard Conditions

Bitter-Pit

This disorder is widespread in Canada and is particularly severe in Nova Scotia where in certain seasons heavy losses are sustained by the growers. Apple varieties which have been found to be most susceptible include Stark, Baldwin, Blenheim, Northern Spy and to a lesser extent Ribston, Gravenstein and Yellow Newtown.

For a description of bitter-pit as it occurs on the tree, and the orchard conditions which favour its development see Part I, "Functional disorders on the tree."

The present section is concerned with the form known as storage pit, which may be considered as a delayed form of tree-pit.

Storage pit is characterized by small, brown, depressed circular or nearly circular spots on the surface of the apple, which extend into the flesh as brown necrotic areas to a depth of one-eighth of an inch. Cut fruits may show numerous similar lesions distributed between the skin and the core area. (Plate IX, Fig. 1.) Large fruits from lightly laden trees and fruits harvested at an immature stage are more susceptible than medium sized fruits from trees carrying a good crop and fruits picked at the proper time.

It is considered that the picking of immature fruit may cause pitting not only of apples which would have pitted if left on the trees, but also of apples which would not have pitted on the tree or in storage, if picking had been delayed long enough. Experiments conducted at the Summerland Experimental Station, British Columbia, have indicated that early picking of heavy crop Newtowns may predispose the fruit to bitter-pit. Record of 180 deliveries of Newtowns handled by commercial packing houses revealed that most lots received before October 1 showed a heavy percentage of bitter-pit, whereas fruit received after that date showed very little.

Storage pit develops more rapidly in common storage than in cold storage, so that prompt cold storage is important. It develops less rapidly at 32° F. than at 40° F.

Water-core and Water-core Breakdown

For a description of water-core as it occurs on the tree and the orchard conditions which favour its development, see Part I, "Functional disorders on the tree."

Water-core occurs in all fruit growing sections in Canada and under certain conditions it affects a large number of varieties. The disorder is particularly severe in Tompkins King as grown in Nova Scotia. Other varieties include Yellow Transparent, Jonathan, Wagener, Cox Orange, Ribston, Rome Beauty, Lobo. Melba, Duchess, Fameuse and Lawfam.

The disorder is characterized by glassy water-soaked areas usually in and around the region of the core of the apples so affected, although any part or the whole of the tissue may be involved. Water-core is frequently associated with sun-scald.

The disorder does not develop after harvest. Fruits so affected when stored at 32° F. may develop breakdown in and around the water-soaked areas, the cells becoming brown and the flesh soft and spongy. On the other hand, it may disappear to a certain extent under ordinary temperature conditions. (Plate IX, Fig. 2.) Susceptible varieties growing under conditions suitable to water-core development should be harvested and marketed as early as possible. (3, 9, 20, 21.)

Cork or Internal Cork, Corky-Core and Corky Breakdown

Cork is of widespread occurrence in Canada, and is found in a large number of varieties. Although the disease originates during the growing season and is not influenced by storage conditions, it should be recognizable by the storage operator. For description see Part I, "Physiological Disorders on the Tree."

Corky breakdown has been observed in McIntosh apples stored at 32° F. and may be described as a secondary physiological disorganization of the cells. Brown discoloration of the healthy tissues occurs around the corky areas finally resulting in the merging of all the necrotic areas in the flesh. (Plate IX, Fig. 3.)

*Fungal Rots in Storage**

A study was made of the fungi responsible for the rotting of apples in storage. Four main types of rot were found and described: I. Blue mould (*Penicillium* spp.) (Plate X, Fig. 2) II. Alternaria rot (*Alternaria* spp.) (Plate XI) III. Grey mould (*Botrytis* spp.) (Plate XI) IV. Black mould (*Rhizopus* spp. and *mucor* spp.) Plate X, Fig. 2). The prevalence of each of these four main types of rot on apples in storage is shown in Table 1. Blue mould and alternaria rot are the only types that are of commercial importance.

TABLE I.—PREVALENCE OF TYPES OF ROTS ON APPLES IN COLD STORAGE

Types	Total No. of rotted fruits	Percentage
I. Blue mould	1,084	61·87
II. Alternaria rot	471	20·88
III. Grey mould	150	8·56
IV. Black mould	32	1·83
Undetermined	15	0·86
Total	1,752	

It will be seen from Table 1 that the most common type of rot is blue mould. This is usually caused by *Penicillium expansum* (Lk) ex Thom., but other species are sometimes responsible. This rot first appears as small, water-soaked, light brown and soft spots, which are irregular in shape, and which may occur on any part of the fruit. As the spots increase in diameter, the colour usually deepens to brown, but the margin remains lighter-coloured and water-soaked. The rot is shallow at first, but increases in depth as the spot enlarges, and frequently the entire fruit is involved. Under favourable conditions of moisture and temperature, small tufts of white mycelium appear. These turn blue-green as soon as spores are formed. The tissues are soft and watery, and are characterized by a musty odour, which usually permeates the entire fruit. The fungus can penetrate through lenticels, but the easiest and most frequent mode of entrance is through bruises, stem punctures, etc., the moist tissues exposed by the broken skin providing an excellent medium for growth.

Alternaria rot is characterized by slightly sunken firm, dark brown to black irregular spots, with margins frequently lighter in colour. There is no mycelium, except where the epidermis is ruptured. It may be anything from grey to black in colour, but is brown when spores are produced. This rot is usually caused by *Alternaria fasciculata* (C. & E.) J. & G., but other species also occur.

Grey mould causes brown to dark brown, slightly sunken, and irregular spots, with a well defined and lighter coloured margin. The decayed tissues are soft, but not watery as in blue mould. The epidermis is tough and slightly wrinkled. The fruit is usually all decayed before mycelium appears on the surface, unless cracks in the skin occur. The mycelium is white, dirty white or grey; that producing spores is brown and the spores appear white. There are two or three species of *Botrytis* which cause this rot.

The rot caused by black mould is light brown to yellowish brown, soft and watery. The skin is thin and soft. A scanty growth of mycelium may protrude where the skin is broken. It is white at first, then turns dark. The fruiting bodies are white when young, but dark when mature.

* The identifcation of the fungi causing the rotting of the fruits, and the description of the microscopic characters of the different rots were made by Mr. H. N. Racicot, Division of Botany and Plant Pathology, Science Service.

TABLE 2.—EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF TYPES OF ROTS, REGARDLESS OF VARIETY OR ORIGIN OF MATERIAL

(Percentage on total rot basis)

Temperature	First sampling types					Second sampling types					Third sampling types				
	I	II	III	IV	Un-identified	I	II	III	IV	Un-identified	I	II	III	IV	Un-identified
30° F.	85·7	0·0	14·3	0·0	0·0	69·4	18·4	10·2	2·0	0·0	74·2	10·6	12·1	1·5	1·5
32° F.	91·7	2·1	4·2	2·1	0·0	54·3	32·1	6·0	6·5	1·1	63·4	24·4	12·2	0·0	0·0
36° F.	91·2	5·9	0·0	2·9	0·0	65·5	24·1	6·9	3·4	0·0	70·7	14·4	9·6	0·0	5·3
40° F.	51·3	42·3	1·3	5·1	0·0	45·4	43·1	7·4	4·2	0·0	60·8	29·6	9·4	0·0	0·2
Sum total on all four temperatures	72·5	21·5	2·4	3·5	0·0	53·9	34·0	7·1	....	....	64·2	24·1	10·3	0·1	1·2

The effect of temperature on the development of types of rots, regardless of variety or origin of material, is shown in Table 2. The data are presented on the basis of the total number of rotted fruits. Type I was not so prevalent at the high as at the low temperatures, this being consistent for the three samplings. Type II on the other hand was greatly suppressed at the low temperatures, while at 40° F. it was nearly as abundant as Type I. It was most abundant in the second sampling. Type III like Type II was much more prevalent at the low temperatures as shown in the first sampling, when there was 14 per cent at 30° F. and only 1 per cent at 40° F. Type IV only appeared in negligible quantity.

Table 3 shows what was consistently observed, namely that there is a temperature above which storage rots increase very perceptibly; there is a marked increase in the occurrence of rots of apples stored at 38° F. compared with those stored at 35° F. This effect was also noted in the case of McIntosh apples stored at 32° F, 36° F. and 39° F. There was a highly significant increase in rots of fruits stored at 39° F. compared with those stored at 36° F. but no significant difference between those stored at 32° F. and 36° F.

TABLE 3.—TOTAL NUMBER OF ROTTED FRUITS AS INFLUENCED BY TEMPERATURE AND FERTILIZER TREATMENT IN GRAVENSTEIN APPLES (PER CENT) TREATMENT

—	32°F.	35°F.	38°F.	Cellar storage
Control (Average 7 plots)	15·2	17·2	35·7	30·2
Complete (Average 10 plots)	10·4	14·3	30·7	26·6
Lime (Average 4 plots)	21·2	23·2	48·0	50·2

These studies would indicate that a storage temperature below 37° F. will result in much less fungal decay than temperatures above that point.

Table 3 also illustrates the considerable effect of fertilizer treatment on the occurrence of rots. Fruits from fertilized trees are more resistant to fungal invasion than fruits from unfertilized trees. Applications of lime increased the occurrence of rots in fruit from trees so treated.

Discussion

Four predominant types of storage rots have been described and the causal fungi identified. Data have been presented which indicate that storage temperatures above 36° F. favour the development of storage rots. These data also indicate that orchard fertilizer treatments may increase or decrease the susceptibility to rots of fruit in storage.

Independent of these effects it has been noted that almost invariably fruit affected by the rots described are those which have suffered mechanical injury. Under proper storage conditions loss from rots can be largely eliminated by careful handling of the fruit through all stages of harvesting and packing. Skin abrasions, bruises, stem punctures and stemless fruit all expose moist tissues which provide an excellent medium for the fungi causing the predominant storage rots.

Too much emphasis cannot be placed on the necessity of careful picking to avoid damaged stems and stemless fruit; bruises from finger pressure; bruises from rough handling or over pressing. If care is taken in these matters loss from rots will be of a negligible nature during the normal life of the fruit.

Jonathan Spot

This disorder is found chiefly on the Jonathan apple, although other varieties such as Gravenstein and Yellow Newtown are sometimes affected. The spots are blackish in colour and are more frequent on the blushed portion. They fade to a light brown when affected apples are removed from storage. The spots have a well defined border and vary in size from minute spots to one-quarter inch in diameter. The spots involve only the skin or a very shallow layer beneath. As the disease progresses, the spots may increase in size, merge and become slightly sunken. The spots are frequently, though not invariably, centred in the lenticels. Spots centred around lenticels frequently show concentric circles of discoloured skin of different intensities. The disorder develops more rapidly at high temperature and it is therefore recommended that susceptible varieties be placed in cold storage at temperatures below 40° F. (1, 9, 20, 21).

Lenticel Spotting (See Plate II, Fig. 4)

This term has been applied to skin spotting, somewhat variable in appearance but having the general characteristic of being centred on lenticels. Owing to the lack of adequate descriptions, it is impossible at this time to subdivide this classification.

In the disorder known as Jonathan spot, the skin spots frequently, though not invariably, centre or border around lenticels. With certain individual fruits, it may be difficult to distinguish between Jonathan spot and lenticel spotting of a different nature. It has been shown by Kidd and West (11) that skin spotting lesions, originating at the lenticels, may be produced as a result of storing a variety of apple with ripe apples of another variety. A similar type of spotting was induced by storing apples in an atmosphere containing ethylene (1 part in 500).

Freezing Injury (See Plate X, Fig. 1)

In view of the relatively low temperatures experienced in certain parts of Canada during the winter months, the occurrence of freezing injury is not uncommon, particularly with fruit that is in transit.

The freezing point of most varieties of apples is approximately 28·5° F. and the injury is governed largely by the severity of the freezing, the length of time the fruit is frozen and the manner in which the fruit is handled.

Apples in the frozen condition exhibit a shrunken, crinkled surface and, when cut, ice crystals are in evidence and the tissue has a glassy appearance. If the freezing is severe and apples are thawed out rapidly, the tissue becomes soft and mushy with water-soaked spots scattered throughout the flesh which are translucent in appearance. On the other hand, in less severe freezing the after effects may appear as a slight browning of the ten main vascular bundles in the apple with perhaps a certain amount of mealiness due to loss of water. (Plate X, Fig. 1.)

Fruit should remain unmoved after freezing and the thawing process carried out slowly at 40° F. Such a method, if adopted, will prevent in many cases any signs of injury from appearing either internally or externally. Such fruit, however, should not be held in storage after it is properly thawed out because of the danger of an early development of mealiness. (6, 9, 16, 23, 24.)

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FIG. 1.—Initial symptoms of drought-spot or superficial cork affecting McIntosh, occurring as irregular small to large light-brown russeted patches on the skin.

FIG. 2.—Later stages of drought spot or superficial cork affecting McIntosh. The affected areas have become darker brown, roughened and cracked. Deep cracks or splits have also occurred.

FIGS. 3 and 4.—Drought-spot or superficial cork affecting Ben Davis.

FIG. 5.—Intermediate stage of drought-spot or superficial cork affecting Stark.

FIG. 6.—Intermediate stage of drought-spot or superficial cork affecting Salome.

FIGS. 1 and 2.- External symptoms of typical tree-pit affecting Spy seedling.

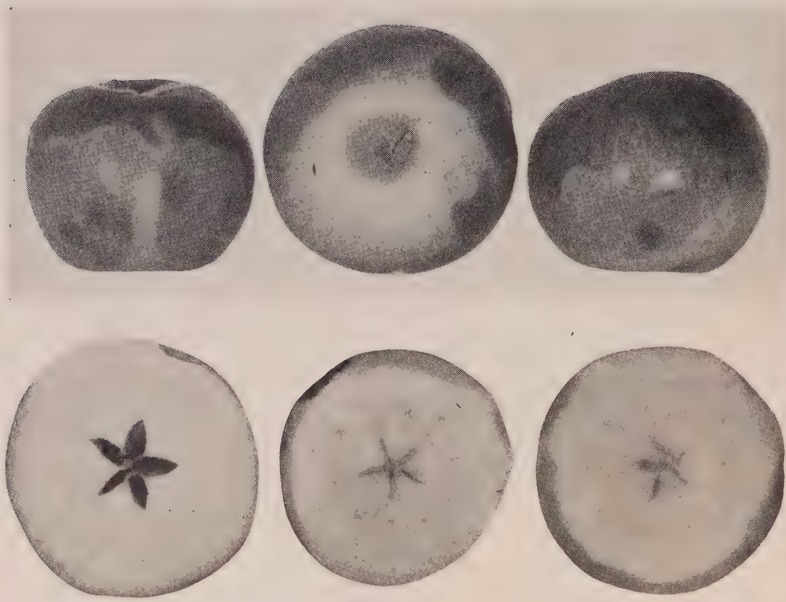
FIG. 3.- External symptoms of internal cork affecting Fameuse. Note distorted and knobby appearance.

FIG. 4.– Lenticel spotting on variety Salome.

FIG. 5.- Tree-pit affecting Baxter seedling. The external symptoms are somewhat different from typical tree-pit, in that the normal coloured pits are encircled by a reddish-brown halo of lighter colour.

FIG. 6.- Blotchy-pit affecting Stark.

FIG. 1.—Internal cork affecting Fameuse.
FIG. 2.—Internal symptoms of typical tree-pit.
FIG. 3.—Corky-core affecting McIntosh.
FIG. 4.—Drought-spot or superficial cork—fruits affected early in their development.



FIGS. 1 and 2.—Soft scald on Wealthy apples stored at 32°F. showing external and internal symptoms.

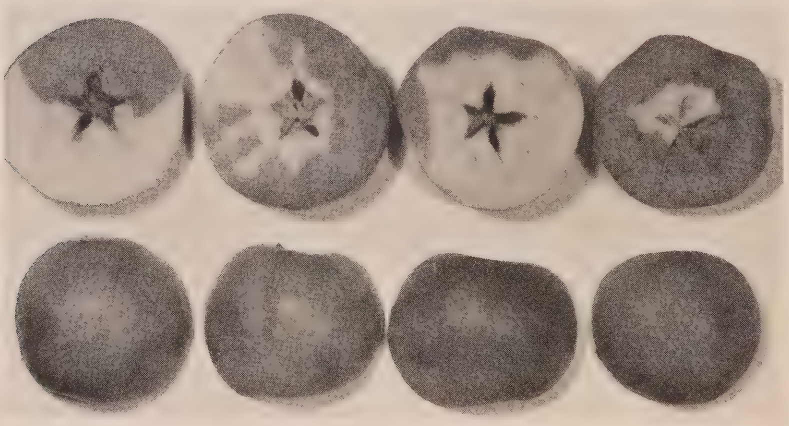


FIG. 3.—Soggy breakdown in Gravenstein apples stored at 32°F. (Note the line of demarcation between the healthy and affected portions on the skin of the second apple from the left in the lower row.)

FIG. 1.—Soggy breakdown ("frog-eye" type) on Blenheim apples stored at 32°F.

FIG. 2.—Internal browning on Yellow Newtown apples stored at 32°F.

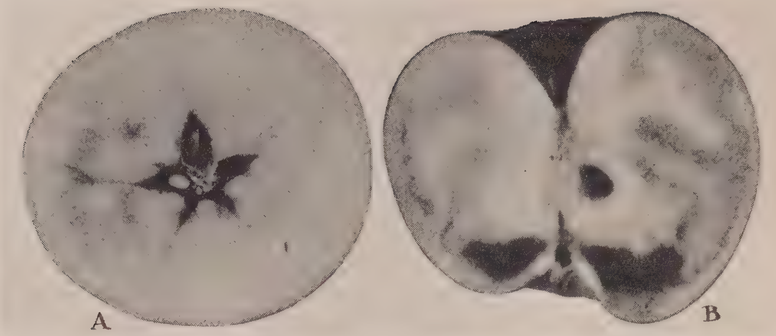


FIG. 1, A and B.—Jonathan breakdown, early and advanced stages of the disease in Jonathan apples.

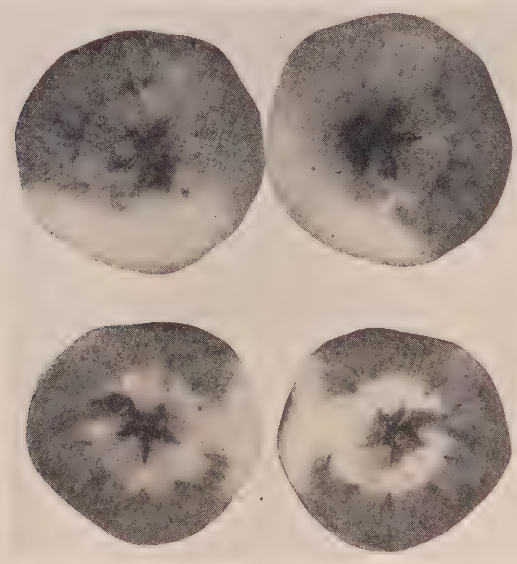


FIG. 2.—Mealy breakdown in Rhode Island Greening apples stored at 38°F.

FIG. 3.—Core flush in McIntosh apples stored at 32° F.; early, intermediate and advanced stages of the disorder.

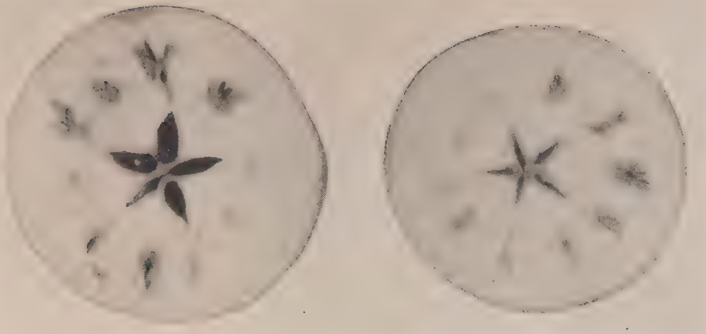


FIG. 1.—Vascular breakdown in Ribston apples stored at 32°F.

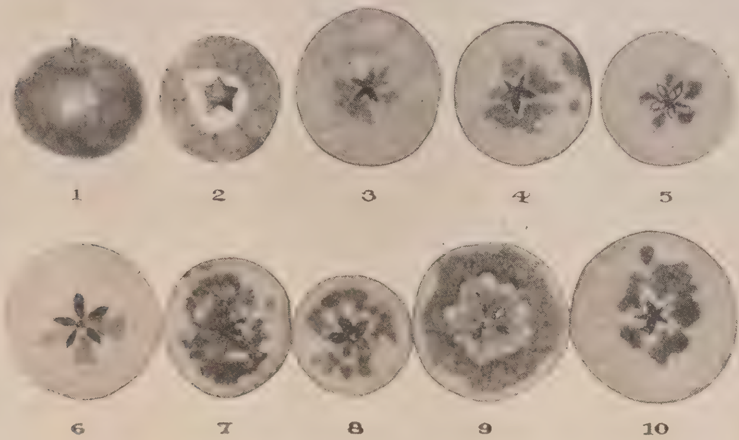


FIG. 2.—Carbon dioxide injury in a number of apple varieties.—
1. McIntosh 3. Baldwin 5. Jonathan 7. Rhode Island Greening 9. King
2. McIntosh 4. Lawfam 6. Golden Russet 8. Cox Orange 10. Northern Spy

FIG. 3.—McIntosh apples showing flesh collapse in the vascular regions after being treated with 100 per cent carbon dioxide for three days at 65°F.

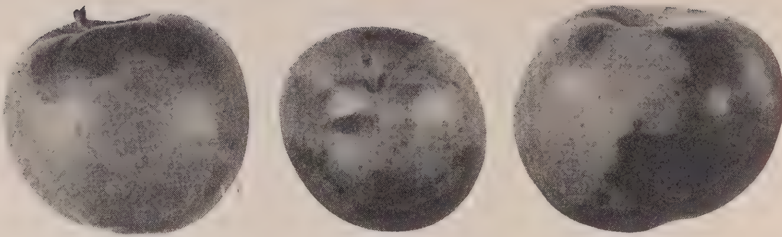


FIG. 1.—Loss of red pigmentation in McIntosh apples stored in 100 per cent nitrogen at 68°F.

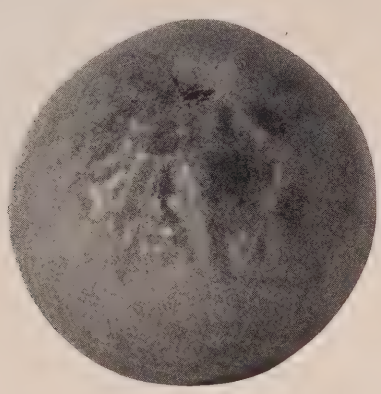


FIG. 2.—External carbon dioxide injury.

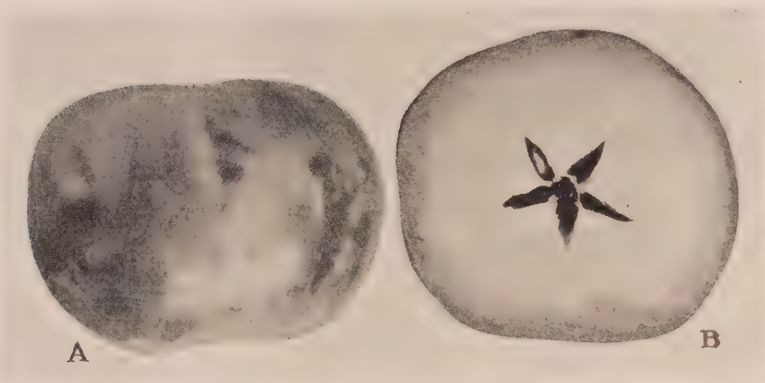


FIG. 3, A and B.—Superficial scald, 3A and scald breakdown, 3B, in Wagener apples stored at 32°F.

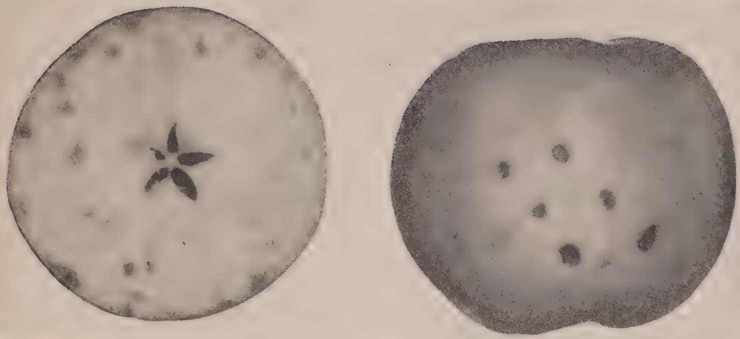


FIG. 1.—Storage pit in Baldwin apples stored in warehouse cellar.

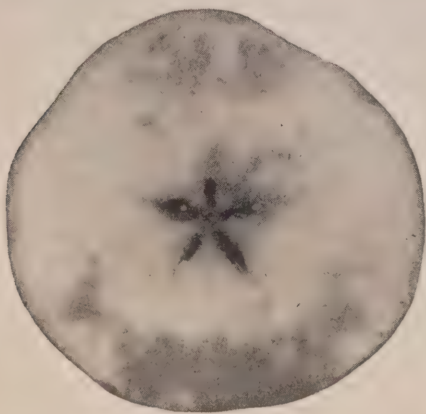


FIG. 2.—Water-core and water-core breakdown in the King apple.

FIG. 3.—Corky breakdown in McIntosh apples.

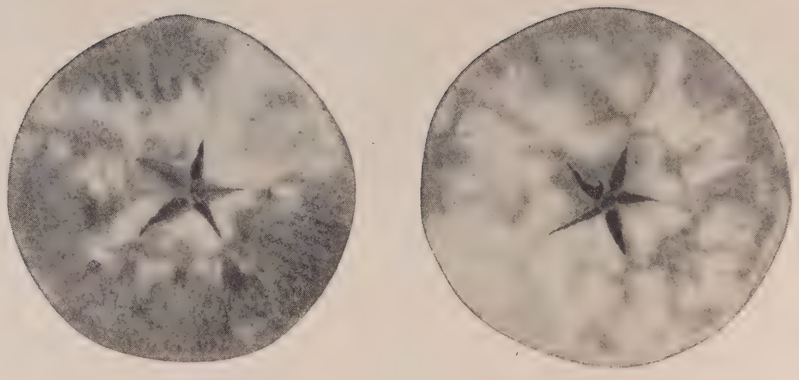
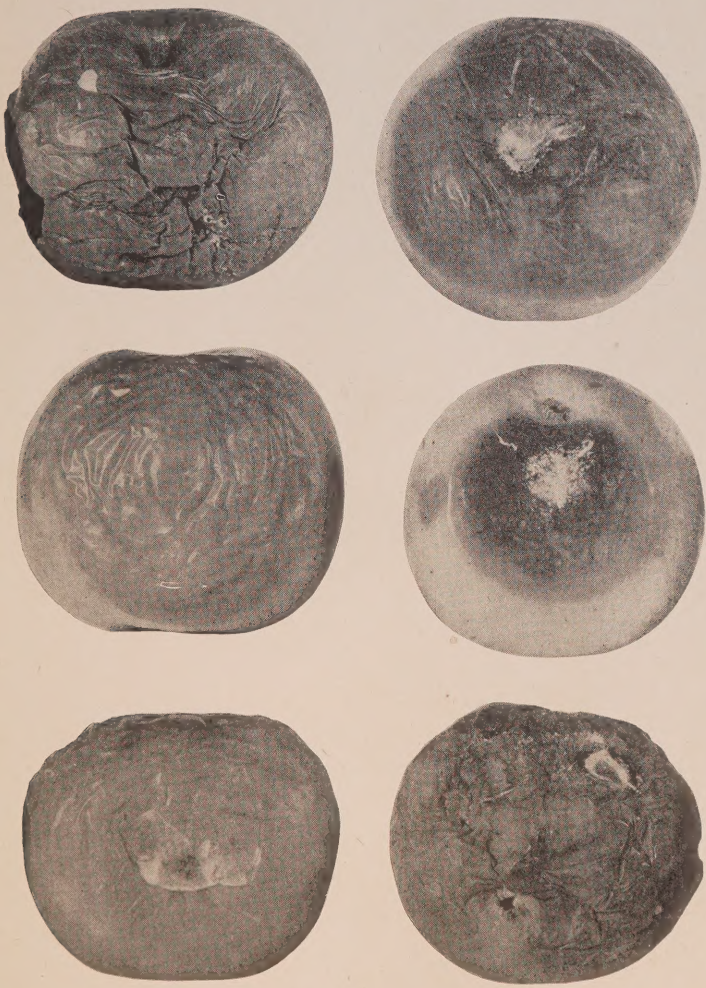


FIG. 1.—Freezing injury in Ribston apples.

FIG. 2.—Upper fruit, storage rot, type IV, black mould (*Rhizopus* spp. and *Mucor* spp.)
Lower fruits, storage rots, Type I, blue mould (*Penicillum* spp.)

PLATE II.



Left fruits, storage rots, Type III, grey mould (*Botrytis* spp.)
Right fruits, storage rots, Type II, Alternaria rot (*Alternaria* spp.)